ARKANSAS

K-12 SCIENCE STANDARDS

EDUCATION FOR A NEW GENERATION

# Chemistry - Integrated

**2016**

## Table of Contents



Notes:

1. Student Performance Expectations (PEs) may be taught in any sequence or grouping within a grade level. Several PEs are described as being "partially addressed in this course" because the same PE is revisited in a subsequent course during which that PE is fully addressed.
2. An asterisk (*) indicates an engineering connection to a practice, core idea, or crosscutting concept.
3. The Clarification Statements are examples and additional guidance for the instructor. AR indicates Arkansas-specific Clarification Statements.
4. The Assessment Boundaries delineate content that may be taught but not assessed in large-scale assessments. AR indicates Arkansas-specific Assessment Boundaries.
5. The section entitled "foundation boxes" is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
6. The examples given (e.g.,) are suggestions for the instructor.
7. Throughout this document, connections are provided to the nature of science as defined by *A Framework for K-12 Science Education* (NRC 2012).
8. Throughout this document, connections are provided to Engineering, Technology, and Applications of Science as defined by *A Framework for K-12 Science Education* (NRC 2012).
9. Each set of PEs lists connections to other disciplinary core ideas (DCIs) within the Arkansas K-12 Science Standards and to the Arkansas English Language Arts Standards, Arkansas Disciplinary Literacy Standards, and the Arkansas Mathematics Standards.

# Arkansas K-12 Science Standards Overview

The Arkansas K-12 Science Standards are based on *A Framework for K-12 Science Education* (NRC 2012) and are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The Arkansas K-12 Science Standards

- reflect science as it is practiced and experienced in the real world,
- build logically from Kindergarten through Grade 12,
- focus on deeper understanding as well as application of content,
- integrate practices, crosscutting concepts, and core ideas, and
- make explicit connections to literacy and math.

As part of teaching the Arkansas K-12 Science Standards, it will be important to instruct and guide students in adopting appropriate safety precautions for their student-directed science investigations. Reducing risk and preventing accidents in science classrooms begin with planning. The following four steps are recommended in carrying out a hazard and risk assessment for any planned lab investigation:

1) Identify all hazards. Hazards may be physical, chemical, health, or environmental.
2) Evaluate the type of risk associated with each hazard.
3) Write the procedure and all necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
4) Prepare for any emergency that might arise in spite of all of the required safety precautions.

According to Arkansas Code Annotated § 6-10-113 (2012) for eye protection, every student and teacher in public schools participating in any chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids is required to wear industrial-quality eye protective devices (eye goggles) at all times while participating in science investigations.

The Arkansas K-12 Science Standards outline the knowledge and science and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions:

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describes core ideas in the science disciplines.

Science and Engineering Practices

The eight practices describe what scientists use to investigate and build models and theories of the world around them or that engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

## Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns*- Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
2. *Cause and effect- Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity*- In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models*- Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation*- Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function*- The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
7. *Stability and change*- For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

## Disciplinary Core Ideas

The disciplinary core ideas describe the content that occurs at each grade or course. The Arkansas K-12 Science Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and are built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

## Connections to the Arkansas English Language Arts Standards

Evidence-based reasoning is the foundation of good scientific practice. The Arkansas K-12 Science Standards incorporate reasoning skills used in language arts to help students improve mastery and understanding in all three disciplines. The Arkansas K-8 Science Committee made every effort to align grade-by-grade with the English language arts (ELA) standards so concepts support what students are learning in their entire curriculum. Connections to specific ELA standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

The intersections between Arkansas K-12 Science Standards and Arkansas ELA Standards teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Reading in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. These practice-based standards help teachers foster a classroom culture where students think and reason together, connecting around the subject matter and core ideas.

## Connections to the Arkansas Disciplinary Literacy Standards

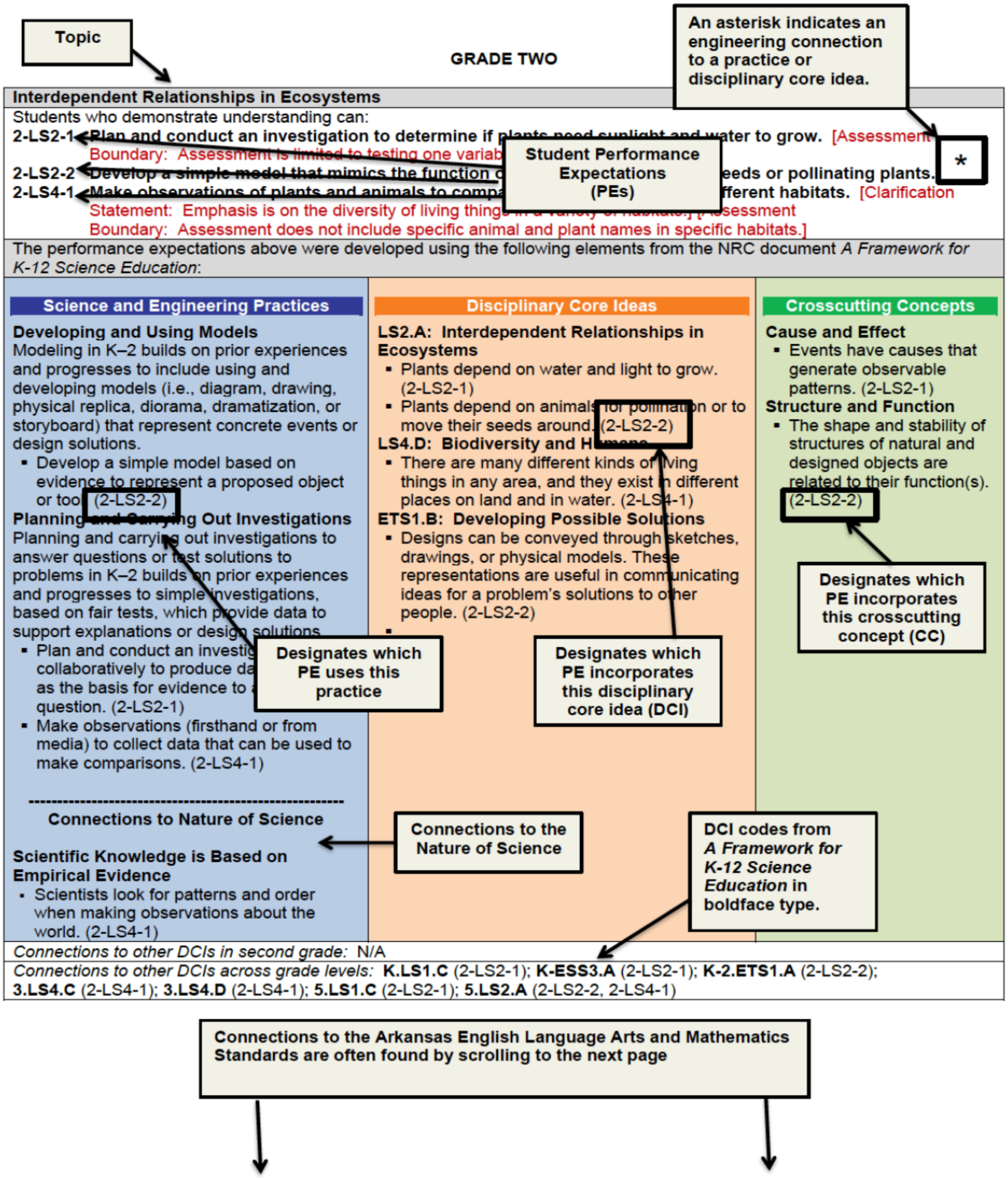
Reading is critical to building knowledge in science. College and career ready reading in science requires an appreciation of the norms and conventions of each discipline, such as the kinds of evidence used in science; an understanding of domain-specific words and phrases; an attention to precise details; and the capacity to evaluate intricate arguments, synthesize complex information, and follow detailed descriptions of events and concepts. When reading scientific and technical texts, students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts. Students must be able to read complex informational texts in science with independence and confidence because the vast majority of reading in college and workforce training programs will be sophisticated nonfiction.

For students, writing is a key means of asserting and defending claims, showing what they know about science, and conveying what they have experienced, imagined, thought, and felt. To be college and career ready writers, students must take task, purpose, and audience into careful consideration, choosing words, information, structures, and formats deliberately. They need to be able to use technology strategically when creating, refining, and collaborating on writing. They have to become adept at gathering information, evaluating sources, and citing material accurately, reporting finds from their research and analysis of sources in a clear and cogent manner. They must have the flexibility, concentration, and fluency to produce high-quality first-draft text under a tight deadline and the capacity to revisit and make improvements to a piece of writing over multiple drafts when circumstances encourage or require it.

## Connections to the Arkansas Mathematics Standards

Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics. To achieve this alignment, the Arkansas K-12 Science Committee made every effort to ensure that the mathematics standards do not outpace or misalign to the grade-by-grade science standards. Connections to specific math standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

# How to Read
# Arkansas K-12 Science



Topic

GRADE TWO

An asterisk indicates an engineering connection to a practice or disciplinary core idea.

**Interdependent Relationships in Ecosystems**

Students who demonstrate understanding can:

**2-LS2-1 Plan and conduct an investigation to determine if plants need sunlight and water to grow.** [Assessment Boundary: Assessment is limited to testing one variab...]

**2-LS2-2 Develop a simple model that mimics the function o... ...eeds or pollinating plants.** *

**2-LS4-1 Make observations of plants and animals to compa... ...fferent habitats.** [Clarification Statement: Emphasis is on the diversity of living thing... ...Assessment Boundary: Assessment does not include specific animal and plant names in specific habitats.]

Student Performance Expectations (PEs)

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
| --- | --- | --- |
| **Developing and Using Models**<br>Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.<br>▪ Develop a simple model based on evidence to represent a proposed object or tool. (2-LS2-2)<br>**Planning and Carrying Out Investigations**<br>Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.<br>▪ Plan and conduct an investig... collaboratively to produce da... as the basis for evidence to a... question. (2-LS2-1)<br>▪ Make observations (firsthand or from media) to collect data that can be used to make comparisons. (2-LS4-1)<br>-----------------------------------------------------<br>**Connections to Nature of Science**<br>**Scientific Knowledge is Based on Empirical Evidence**<br>▪ Scientists look for patterns and order when making observations about the world. (2-LS4-1) | **LS2.A: Interdependent Relationships in Ecosystems**<br>▪ Plants depend on water and light to grow. (2-LS2-1)<br>▪ Plants depend on animals for pollination or to move their seeds around. (2-LS2-2)<br>**LS4.D: Biodiversity and Humans**<br>▪ There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)<br>**ETS1.B: Developing Possible Solutions**<br>▪ Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (2-LS2-2)<br>▪ | **Cause and Effect**<br>▪ Events have causes that generate observable patterns. (2-LS2-1)<br>**Structure and Function**<br>▪ The shape and stability of structures of natural and designed objects are related to their function(s). (2-LS2-2) |

Designates which PE uses this practice

Designates which PE incorporates this disciplinary core idea (DCI)

Designates which PE incorporates this crosscutting concept (CC)

Connections to the Nature of Science

DCI codes from *A Framework for K-12 Science Education* in boldface type.

*Connections to other DCIs in second grade:* N/A

*Connections to other DCIs across grade levels:* **K.LS1.C** (2-LS2-1); **K-ESS3.A** (2-LS2-1); **K-2.ETS1.A** (2-LS2-2); **3.LS4.C** (2-LS4-1); **3.LS4.D** (2-LS4-1); **5.LS1.C** (2-LS2-1); **5.LS2.A** (2-LS2-2, 2-LS4-1)

Connections to the Arkansas English Language Arts and Mathematics Standards are often found by scrolling to the next page

## Chemistry - Integrated Learning Progression Chart

| Topic 1: Matter and Chemical Reactions | Topic 2: Nuclear Reactions | Topic 3: Energy Flow | Topic 4: Waves | Topic 5: Forces |
|---|---|---|---|---|
| AR CI-PS1-1 | CI-PS1-8 | CI-PS1-4 | AR CI-PS4-1 | AR CI-PS2-1 |
| AR CI-PS1-2 | CI-ESS1-1 | CI-PS1-5 | CI-PS4-3 | CI-PS2-2 |
| AR CI-PS1-3 | CI-ESS1-3 | AR CI-PS3-1 | CI-PS4-4 | CI-PS2-4 |
| CI-PS1-6 | CI-ESS1-6 | CI-ESS1-2 | CI-PS4-5 | CI-PS3-5 |
| AR CI-PS1-7 | AR CI2-ETS1-1 | CI-ESS2-3 | AR CI4-ETS1-4 | CI-ESS1-4 |
| CI-ESS2-5 | AR CI2-ETS1-2 | AR CI-ESS3-4 | | AR CI5-ETS1-2 |
| AR CI1-ETS1-2 | AR CI2-ETS1-3 | AR CI3-ETS1-1 | | |
| | AR CI2-ETS1-4 | | | |

Arkansas Clarification Statement/Assessment Boundary (AR)

# Chemistry - Integrated Course Overview

(Course code 421000)

The Arkansas K-12 Science Standards for chemistry - integrated is an integrated science course that focuses on conceptual understanding of the foundational chemistry and physics core ideas, science and engineering practices, and crosscutting concepts and is composed of chemistry, physics, Earth and space science, and engineering design standards. It is recommended that students be enrolled in algebra II concurrently with this course. Teachers with chemistry, physics, physical Science, physical/Earth, or physics/math licenses are qualified to teach this course. Students will earn a 1 unit of Smart Core/chemistry credit for graduation.

Students in chemistry - integrated fully develop their understanding of the core ideas in the physical and Earth and space sciences. These ideas include the more complex concepts from chemistry, physics, and Earth science but are intended to leave room for expanded study in career-focus high school courses. The performance expectations (standards) build on the physical science ideas and skills and allow high school students to explain more in-depth phenomena foundational to chemistry, physics, and Earth and space sciences as well. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing usable knowledge to explain ideas across these science disciplines. In the physical science performance expectations at the high school level, there is a focus on several scientific practices.

Connections with other science disciplines help high school students develop these capabilities in various contexts. For example, in the environmental science course students re-apply their engineering capabilities to reduce human impacts on Earth systems and improve social and environmental cost-benefit ratios (ENV-ESS3-3, ENV-ESS3-4).

Additionally, it should be noted that the chemistry - integrated standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

Students in Chemistry - Integrated also continue their ability to develop possible solutions for major global problems with engineering design challenges. At the high school level, students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to light the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages:

- **Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which the world population is growing and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.
- **Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria but to also recognize that criteria needs to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.
- **Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, anticipate possible societal and environmental impacts, and test the validity of their simulations by comparison to the real world.

# Chemistry - Integrated Topics Overview

The performance expectations in **Topic 1: Matter and Chemical Reactions** help students answer these questions:

- How can the structure and properties of matter be explained?
- How do substances combine or change (react) to make new substances?
- How can patterns be used to characterize and predict chemical reactions?

Students develop an understanding of the substructure of atoms and provide more mechanistic explanations of the properties of substances. Students learn how to use the periodic table as a tool to explain and predict the properties of elements. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. Students apply an understanding of the process of optimization in engineering design to chemical reaction systems.

The performance expectations in **Topic 2: Nuclear Reactions** help students answer these questions:

- How do nuclear reactions differ from chemical reactions?
- What nuclear processes are associated with stars?
- How are elements transformed through nuclear processes?

Students develop an understanding of the formation and abundance of elements, radioactivity, the release of energy from the sun and other stars, and the generation of nuclear power.

The performance expectations in **Topic 3: Energy Flow** help students answer these questions:

- How does energy flow in a system?
- How is energy transferred?
- How is energy conserved?

This topic is organized into four ideas: definitions of energy, conservation of energy and energy transfer, the relationship between energy and forces, and energy in chemical process and everyday life. Students develop an understanding of energy as a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. The total change of energy in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy at both the macroscopic and the atomic scale can be accounted for as either motions of particles or energy associated with the configuration (relative positions) of particles. In some cases, the energy associated with the configuration of particles can be thought of as stored in fields. Additionally, students explore energy interactions associated with geologic processes such as plate tectonics, seismic waves, and convection. Students demonstrate understanding of engineering principles by designing, building, and refining devices associated with the conversion of energy.

The performance expectations in **Topic 4: Waves** help students answer these questions:

- How do the properties of waves affect their function?
- How are waves used to transfer energy?
- How are waves used to send and store information?
- How do electromagnetic radiation and matter interact?

This topic is organized into three ideas: wave properties, electromagnetic radiation, and information technologies/instrumentation. Students develop an understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and be used to investigate nature on many scales. Models of electromagnetic radiation as either a wave of changing electric/magnetic fields and/or as particles are developed and used. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students demonstrate understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

The performance expectations in **Topic 5: Forces** help students answer these questions:

- How do forces cause microscopic to macroscopic changes?
- How can one explain and predict interactions between objects and within systems of objects?
- How do intermolecular forces determine properties such as melting point, boiling point, vapor pressure, and surface tension?
- How does the net momentum of particles on the microscale relate to Kinetic Molecular Theory?
- How can forces and momentum be modeled mathematically?

This topic is organized into two ideas: forces and motion as well as types of interactions. Students are expected to develop an understanding of forces and interactions as they are described by Newton's laws. Students develop an understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students use Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects. Students apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

## Chemistry - Integrated

| Topic 1: Matter and Chemical Reactions |
| --- |

Students who demonstrate understanding can:

**CI-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [AR Clarification Statement: This PE is fully addressed in this course. Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [AR Assessment Boundary: Assessment is limited to main group elements. Assessment does not include exceptions to periodic trends.]

**CI-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [AR Clarification Statement: This PE is fully addressed in this course. Examples of chemical reactions could include the reaction of sodium and chlorine, carbon and oxygen, and carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

**CI-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on understanding the strengths of forces between particles, including identifying and naming specific intermolecular forces (dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

**CI-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]

**CI-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on demonstrating conservation of mass through the mole concept and stoichiometry. Emphasis is on assessing students' use of mathematical thinking, not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

**CI-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

**CI1-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. .** [AR Clarification Statement: Examples of real-world problems could include wastewater treatment, production of biofuels, and the impact of heavy metals or phosphate pollutants on the environment.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.<br>▪ Use a model to predict the relationships between systems or between components of a system. (CI-PS1-1)<br>**Planning and Carrying Out Investigations**<br>Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.<br>▪ Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (CI-PS1-3, CI-ESS2-5)<br>**Using Mathematics and Computational Thinking**<br>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. | **PS1.A: Structure and Properties of Matter**<br>▪ Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (CI-PS1-1)<br>▪ The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (CI-PS1-1, CI-PS1-2)<br>▪ The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (CI-PS1-3)<br>**PS1.B: Chemical Reactions**<br>▪ In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (CI-PS1-6)<br>▪ The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (CI-PS1-2, CI-PS1-7)<br>**PS2.B: Types of Interactions**<br>▪ Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (CI-PS1-1, CI-PS1-3) | **Patterns**<br>▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (CI-PS1-1, CI-PS1-2, CI-PS1-3)<br>**Energy and Matter**<br>▪ The total amount of energy and matter in closed systems is conserved. (CI-PS1-7)<br>**Stability and Change**<br>▪ Much of science deals with constructing explanations of how things change and how they remain stable. (CI-PS1-6)<br>**Structure and Function**<br>▪ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (CI-ESS2-5)<br>---------------------------------------<br>***Connections to Nature of Science***<br>**Scientific Knowledge Assumes an Order and Consistency in Natural Systems**<br>▪ Science assumes the universe is a vast single system in which basic laws are consistent. (CI-PS1-7) |

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- Use mathematical representations of phenomena to support claims. (CI-PS1-7)

**Constructing Explanations and Designing Solutions**
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (CI-PS1-2)
- Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI-PS1-6)
- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI1-ETS1-2)

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**PS2.B: Types of Interactions**

- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (CI-PS1-1,CI-PS1-3)

**ESS2.C: The Roles of Water in Earth's Surface Processes**

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (CI-ESS2-5)

**ETS1.C: Optimizing the Design Solution**

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (CI-PS1-6)

**ETS1.C: Optimizing the Design Solution**

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (CI1-ETS1-2)

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*Connections to other DCIs in this course:* **CI.ESS2.C** (CI-PS1-2, CI-PS1-3); **CI.PS1.A** (CI-ESS2-5); **CI.PS1.B** (CI-ESS2-5); **CI.PS3.B** (CI-ESS2-5)

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*Connections to DCIs across grade-bands:* **7.PS1.A** (CI-PS1-1, CI-PS1-2, CI-PS1-3, CI-PS1-7, CI-ESS2-5); **7.PS1.B**, (CI-PS1-1, CI-PS1-2, CI-PS1-6, CI-PS1-7); **8.PS2.B** (CI-PS1-3); **7.ESS2.A** (CI-PS1-7); **8.PS4.B** (CI-ESS2-5); **7.ESS2.A** (CI-ESS2-5); **7.ESS2.C** (CI-ESS2-5); **6.ESS2.D** (CI-ESS2-5); **6-8.ETS1.A** (CI1-ETS1-2); **6-8.ETS1.B** (CI1-ETS1-2); **6-8.ETS1.C** (CI1-ETS1-2)

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*Connections to the Arkansas Disciplinary Literacy Standards:*
**RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (CI-PS1-1)

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| **RST.11-12.1** | Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (CI-PS1-3) |
| **WHST.9-12.2** | Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (CI-PS1-2) |
| **WHST.9-12.5** | Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (CI-PS1-2) |
| **WHST.9-12.7** | Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (CI-PS1-3, CI-PS1-6, CI-ESS2-5) |
| **WHST.11-12.8** | Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (CI-PS1-3) |
| **WHST.9-12.9** | Draw evidence from informational texts to support analysis, reflection, and research. (CI-PS1-3) |

*Connections to the Arkansas Mathematics Standards:*

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| **MP.2** | Reason abstractly and quantitatively. (CI-PS1-7) |
| **MP.4** | Model with mathematics. (CI1-ETS1-2) |
| **HSN.Q.A.1** | Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (CI-PS1-2, CI-PS1-3, CI-PS1-7) |
| **HSN.Q.A.2** | Define appropriate quantities for the purpose of descriptive modeling. (CI-PS1-7) |
| **HSN.Q.A.3** | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (CI-PS1-2, CI-PS1-3, CI-PS1-7, CI-ESS2-5) |

# Chemistry - Integrated

## Topic 2: Nuclear Reactions

Students who demonstrate understanding can:

**CI-PS1-8** **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]

**CI-ESS1-1** **Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.** [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] [Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.]

**CI-ESS1-3** **Communicate scientific ideas about the way stars, over their life cycle, produce elements.** [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.]

**CI-ESS1-6** **Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.** [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

**CI2-ETS1-1** **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** [AR Clarification Statement: Emphasis is on the specific needs and constraints involved with power generation.]

**CI2-ETS1-2** **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** [AR Clarification Statement: Emphasis is on nuclear power management.]

**CI2-ETS1-3** **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** [AR Clarification Statement: Emphasis is on the relationship between nuclear fission and fusion.]

**CI2-ETS1-4** **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** [AR Clarification Statement: Examples could include nuclear weapons and nuclear medicine (radioisotopes or radiation therapy).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
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| **Developing and Using Models**<br>Modeling in 9–12 builds on K–8 experiences and progresses to using, | **ESS1.A: The Universe and Its Stars** | **Scale, Proportion, and Quantity**<br>▪ The significance of a phenomenon is dependent on |

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| synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).<br>▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (CI-ESS1-1, CI-PS1-8)<br>**Constructing Explanations and Designing Solutions**<br>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.<br>▪ Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (CI-ESS1-6)<br>▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI2-ETS1-2)<br>▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI2-ETS1-3)<br>**Obtaining, Evaluating, and Communicating Information**<br>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.<br>▪ Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, | ▪ The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (CI-ESS1-1)<br>▪ The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (CI-ESS1-3)<br>▪ Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (CI-ESS1-3)<br>**ESS1.C: The History of Planet Earth**<br>▪ Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. (CI-ESS1-6)<br>**PS1.C: Nuclear Processes**<br>▪ Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (CI-ESS1-6)<br>**PS3.D: Energy in Chemical Processes and Everyday Life**<br>▪ Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (CI-ESS1-1)<br>**PS1.C: Nuclear Processes** | the scale, proportion, and quantity at which it occurs. (CI-ESS1-1)<br>**Energy and Matter**<br>▪ In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (CI-PS1-8, CI-ESS1-3)<br>**Stability and Change**<br>▪ Much of science deals with constructing explanations of how things change and how they remain stable. (CI-ESS1-6)<br>**Systems and System Models**<br>▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (CI2-ETS1-4)<br>---------------------------------------------<br>***Connections to Engineering, Technology, and Applications of Science***<br>**Influence of Science, Engineering, and Technology on Society and the Natural World**<br>▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (CI2-ETS1-1, CI2-ETS1-3) |

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| graphically, textually, and mathematically). (CI-ESS1-3)<br>**Asking Questions and Defining Problems**<br>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.<br>▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (CI2-ETS1-1)<br>**Using Mathematics and Computational Thinking**<br>Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.<br>▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (CI2-ETS1-4)<br><br>**---------------------------------------------**<br>***Connections to Nature of Science***<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>▪ A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the | ▪ Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (CI-PS1-8)<br>**ETS1.A: Defining and Delimiting Engineering Problems**<br>▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (CI2-ETS1-1)<br>▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (CI2-ETS1-1)<br>**ETS1.B: Developing Possible Solutions**<br>▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (CI2-ETS1-3)<br>▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (CI2-ETS1-4) | |

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| theory does not accommodate, the theory is generally modified in light of this new evidence. (CI-ESS1-6)<br>▪ Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (CI-ESS1-6) | **ETS1.C: Optimizing the Design Solution**<br>▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (CI2-ETS1-2) | |

*Connections to other DCIs in this course:* **CI.PS1.A** (CI-ESS1-3); **CI.PS1.C** (CI-ESS1-1, CI-ESS1-3); **CI.PS2.A** (CI-ESS1-6); **CI.PS2.B** (CI-ESS1-6); **CI.PS3.A** (CI-ESS1-1, CI-PS1-8)**; CI.PS3.D** (CI-PS1-8); **CI.ESS1.A** (CI-PS1-8); **CI.ESS1.C** (CI-PS1-8)

*Connections of DCIs across grade-bands:* **7.PS1.A** (CI-ESS1-1, CI-ESS1-3, CI-PS1-8); **CI.PS1.B** (CI-PS1-8); **8.PS2.B** (CI-ESS1-6); **8.PS4.B** (CI-ESS1-1); **8.ESS1.A** (CI-ESS1-1, CI-ESS1-3); **8.ESS1.B** (CI-ESS1-6); **8.ESS1.C** (CI-ESS1-6); **7.ESS2.A** (CI-ESS1-1, CI-ESS1-6, CI-PS1-8); **7.ESS2.B** (CI-ESS1-6); **6.ESS2.D** (CI-ESS1-1); **6-8.ETS1.A** (CI2-ETS1-1, CI2-ETS1-2, CI2-ETS1-3, CI2-ETS1-4); **6-8.ETS1.B** (CI2-ETS1-2, CI2-ETS1-3, CI2-ETS1-4); **6-8.ETS1.C** (CI2-ETS1-2, CI2-ETS1-4)

*Connections to the Arkansas Disciplinary Literacy Standards:*

**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (CI-ESS1-1, CI-ESS1-6)

**RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (CI2-ETS1-1, CI2-ETS1-3)

**RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (CI-ESS1-6, CI2-ETS1-1, CI2-ETS1-3)

**RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (CI2-ETS1-1, CI2-ETS1-3)

**WHST.9-12.1** Write arguments focused on discipline-specific content. (CI-ESS1-6)

**WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (CI-ESS1-3)

*Connections to the Arkansas Language Arts Standards:*

**SL.11-12.4** Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. (CI-ESS1-3)

*Connections to the Arkansas Mathematics Standards:*

**MP.2** Reason abstractly and quantitatively. (CI-ESS1-1, CI-ESS1-3, CI-ESS1-6, CI2-ETS1-1, CI2-ETS1-3, CI2-ETS1-4)

**MP.4** Model with mathematics. (CI-ESS1-1, CI-PS1-8, CI2-ETS1-1, CI2-ETS1-2, CI2-ETS1-3, CI2-ETS1-4)

**HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (CI-ESS1-1, CI-ESS1-6, CI-PS1-8)

**HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (CI-ESS1-1, CI-PS1-8,

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| | CI-ESS1-6) |
| **HSN.Q.A.3** | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (CI-ESS1-1, CI-ESS1-6, CI-PS1-8) |
| **HSA.SSE.A.1** | Interpret expressions that represent a quantity in terms of its context; interpret parts of an expression using appropriate vocabulary, such as terms, factors, and coefficients; interpret complicated expressions by viewing one or more of their parts as a single entity. (CI-ESS1-1) |
| **HSA.CED.A.2** | Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on coordinate plane. (CI-ESS1-1) |
| **HSA.CED.A.4** | Rearrange literal equations using the properties of equality. (CI-ESS1-1) |
| **HSF.IF.B.5** | Relate the domain of a function to its graph; relate the domain of a function to the quantitative relationship it describes. (CI-ESS1-6) |
| **HSS.ID.B.6** | Represent data on two quantitative variables on a scatter plot, and describe how those variables are related; fit a function to the data; use functions fitted to solve problems in the context of data; informally assess the fit of a function by plotting and analyzing residuals. (CI-ESS1-6) |

## Chemistry - Integrated

### Topic 3: Energy Flow

Students who demonstrate understanding can:

**CI-PS1-4** **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

**CI-PS1-5** **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

**CI-PS3-1** **Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on explaining the meaning of mathematical expressions used in the model.] [AR Assessment Boundary: Assessment is limited to systems of two or three components and to thermal energy, kinetic energy, and the energies in gravitational, magnetic, or electric fields.]

**CI-ESS1-2** **Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.** [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

**CI-ESS2-3** **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

**CI-ESS3-4** **Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*** [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on the impacts of human activities on physical systems. Examples of data on the impacts of human activities could include the quantities and types of pollutants released (fertilizer, surface mining, and nuclear byproducts). Examples for limiting future impacts could range from local efforts (reducing, reusing, and recycling resources) to large-scale engineering design solutions (nuclear power, photovoltaic cells, wind power, and water power).]

**CI3-ETS1-1** **Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** [AR Clarification Statement: Examples of the applications could include renewable energy resources (solar cells and wind farms), the Haber process for the production of fertilizers, and increased fuel efficiency of combustion engines.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.<br>▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (CI-PS1-4, CI-ESS2-3)<br>**Constructing Explanations and Designing Solutions**<br>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.<br>▪ Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (CI-PS1-5)<br>▪ Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (CI-ESS1-2)<br>▪ Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI-ESS3-4)<br>**Using Mathematics and Computational Thinking**<br>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including | **PS1.A: Structure and Properties of Matter**<br>▪ A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (CI-PS1-4)<br>**PS1.B: Chemical Reactions**<br>▪ Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (CI-PS1-4, CI-PS1-5)<br>**PS3.A: Definitions of Energy**<br>▪ Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (CI-PS3-1)<br>**PS3.B: Conservation of Energy and Energy Transfer**<br>▪ Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (CI-PS3-1)<br>▪ Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (CI-PS3-1)<br>▪ Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression | **Patterns**<br>▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (CI-PS1-5)<br>**Energy and Matter**<br>▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (CI-PS1-4)<br>▪ Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. (CI-ESS1-2)<br>▪ Energy drives the cycling of matter within and between systems. (CI-ESS2-3)<br>**Systems and System Models**<br>▪ Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (CI-PS3-1)<br>**Stability and Change**<br>▪ Feedback (negative or positive) can stabilize or destabilize a system. (CI-ESS3-4)<br>----------------------------------------<br>***Connections to Nature of Science***<br>**Scientific Knowledge Assumes an Order and** |

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| trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.<br>▪ Create a computational model or simulation of a phenomenon, designed device, process, or system. (CI-PS3-1)<br>**Asking Questions and Defining Problems**<br>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.<br>▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (CI3-ETS1-1) | of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (CI-PS3-1)<br>▪ The availability of energy limits what can occur in any system. (CI-PS3-1)<br>**PS4.B Electromagnetic Radiation**<br>▪ Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (CI-ESS1-2)<br>**ESS1.A: The Universe and Its Stars**<br>▪ The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (CI-ESS1-2)<br>▪ The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (CI-ESS1-2)<br>▪ Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (CI-ESS1-2)<br>**ESS2.A: Earth Materials and Systems**<br>▪ Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a | **Consistency in Natural Systems**<br>▪ Science assumes the universe is a vast single system in which basic laws are consistent. (CI-PS3-1, CI-ESS1-2)<br>▪ Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (CI-ESS1-2)<br>----------------------------------------<br>***Connections to Engineering, Technology, and Applications of Science***<br>**Interdependence of Science, Engineering, and Technology**<br>▪ Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (CI-ESS1-2, CI-ESS2-3)<br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>▪ Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (CI-ESS3-4)<br>▪ New technologies can have deep impacts on society and the environment, including some that were not |

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| | solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (CI-ESS2-3)<br>**ESS2.B: Plate Tectonics and Large-Scale System Interactions**<br>▪ The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. (CI-ESS2-3)<br>**ESS3.C: Human Impacts on Earth Systems**<br>▪ Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (CI-ESS3-4)<br>**ETS1.A: Defining and Delimiting Engineering Problems**<br>▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (CI3-ETS1-1)<br>▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (CI3-ETS1-1) | anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (CI3-ETS1-1) |

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| | **ETS1.B: Developing Possible Solutions**<br>▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (CI-ESS3-4) | |

*Connections to other DCIs in this course:* **CI.PS1.A** (CI-ESS1-2); **CI.PS1.B** (CI-PS3-1); **CI.PS1.C** (CI-ESS1-2); **CI.PS2.B** (CI-ESS2-3); **CI.PS3.A** (CI-PS1-4, CI-PS1-5, CI-ESS1-2); **CI.PS4.A** (CI-ESS1-2); **CI.ESS1.A** (CI-PS1-8, CI-PS3-1)

*Connections to DCIs across grade-bands:* **7.PS1.A** (CI-PS1-4, CI-ESS1-2, CI-ESS2-3); **7.PS1.B** (CI-PS1-4, CI-PS1-5, CI-ESS2-3); **8.PS2.B** (CI-PS1-4, CI-PS1-5,CI-ESS2-3); **8.PS3.A** (CI-PS1-5, CI-ESS2-3, CI-ESS2-3); **8.PS3.B** (CI-PS1-5),(CI-PS3-1),(CI-ESS2-3); **6.PS3.D** (CI-PS1-4); **8.PS4.B** (CI-ESS1-2); **8.ESS1.A** (CI-ESS1-2); **7.ESS2.A** (CI-PS3-1, CI-ESS2-3, CI-ESS3-4); **7.ESS2.B** (CI-ESS2-3); **7.ESS3.B** (CI-ESS3-4); **6.ESS3.C** (CI-ESS3-4); **6.ESS3.D** (CI-ESS3-4); **6-8.ETS1.A** (CI3-ETS1-1)

*Connections to the Arkansas Disciplinary Literacy Standards:*

**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (CI-PS1-5, CI-ESS1-2, CI-ESS2-3, CI-ESS3-4)

**RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (CI3-ETS1-1)

**RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (CI-ESS3-4, CI3-ETS1-1)

**RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (CI3-ETS1-1)

**WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (CI-PS1-5, CI-ESS1-2)

*Connections to the Arkansas English Language Arts Standards:*

**SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (CI-PS1-4, CI-PS3-1, CI-ESS2-3)

*Connections to the Arkansas Mathematics Standards:*

**MP.2** Reason abstractly and quantitatively. (CI-PS1-5, CI-PS3-1, CI-ESS1-2, CI-ESS2-3, CI-ESS3-4, CI3-ETS1-1)

**MP.4** Model with mathematics. (CI-PS1-4, CI-PS3-1, CI-ESS2-3, CI3-ETS1-1)

**HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (CI-PS1-4, CI-PS1-5, CI-PS3-1, CI-ESS1-2, CI-ESS2-3, CI-ESS3-4)

**HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (CI-PS1-4, CI-PS3-1, CI-ESS1-2, CI-ESS2-3, CI-ESS3-4)

**HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (CI-PS1-4, CI-PS1-5, CI-PS3-1, CI-ESS1-2, CI-ESS2-3, CI-ESS3-4)

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| **HSA.SSE.A.1** | Interpret expressions that represent a quantity in terms of its context; interpret parts of an expression using appropriate vocabulary, such as terms, factors, and coefficients; interpret complicated expressions by viewing one or more of their parts as a single entity. (CI-ESS1-2) |
| **HSA.CED.A.2** | Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on a coordinate plane. (CI-ESS1-2) |
| **HSA.CED.A.4** | Rearrange literal equations using the properties of equality. (CI-ESS1-2) |

## Topic 4: Waves

Students who demonstrate understanding can:

**CI-PS4-1** **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [AR Clarification Statement: This PE is fully addressed in this course. Examples of data could include electromagnetic radiation traveling in a vacuum and glass as well as seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

**CI-PS4-3** **Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]

**CI-PS4-4** **Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.** [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [Assessment Boundary: Assessment is limited to qualitative descriptions.]

**CI-PS4-5** **Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

**CI4-ETS1-4** **Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.** [AR Clarification Statement: Examples could include information transfer using fiber optics, radio waves, and medical imaging.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Using Mathematics and Computational Thinking**<br>Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.<br>▪ Use mathematical representations of phenomena or design solutions to | **PS3.D: Energy in Chemical Processes**<br>▪ Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (CI-PS4-5)<br>**PS4.A: Wave Properties**<br>▪ The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (CI-PS4-1) | **Cause and Effect**<br>▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (CI-PS4-1)<br>▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about |

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| describe and/or support claims and/or explanations. (CI-PS4-1)<br>▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (CI4-ETS1-4)<br>**Engaging in Argument from Evidence**<br>Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.<br>▪ Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (CI-PS4-3)<br>**Obtaining, Evaluating, and Communicating Information**<br>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.<br>▪ Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (CI-PS4-4)<br>▪ Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (CI-PS4-5)<br>---------------------------------------------------<br>***Connections to Nature of Science***<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>▪ A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment | ▪ Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (CI-PS4-5)<br>▪ [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (CI-PS4-3)<br>**PS4.B: Electromagnetic Radiation**<br>▪ Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (CI-PS4-3)<br>▪ When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (CI-PS4-4)<br>▪ Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (CI-PS4-5)<br>**PS4.C: Information Technologies and Instrumentation**<br>▪ Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, and scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals | smaller scale mechanisms within the system. (CI-PS4-4)<br>▪ Systems can be designed to cause a desired effect. (CI-PS4-5)<br>**Systems and System Models**<br>▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (CI-PS4-3, CI4-ETS1-4)<br><br>-------------------------------------<br>***Connections to Engineering, Technology, and Applications of Science***<br><br>**Interdependence of Science, Engineering, and Technology**<br>▪ Science and engineering complement each other in the cycle known as research and development (R&D). (CI-PS4-5)<br>**Influence of Engineering, Technology, and Science on Society and the Natural World**<br>▪ Modern civilization depends on major technological systems. (CI-PS4-5) |

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| and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (CI-PS4-3) | and for storing and interpreting the information contained in them. (CI-PS4-5)<br>**ETS1.B: Developing Possible Solutions**<br>▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (CI4-ETS1-4) | |

*Connections to other DCIs in this course:* **CI.PS1.C** (CI-PS4-4); **CI.PS3.A** (CI-PS4-4, CI-PS4-5); **CI.PS3.D** (CI-PS4-3, CI-PS4-4); **CI.ESS1.A** (CI-PS4-3); **CI.ESS2.A** (CI-PS4-1); **CI.ESS2.D** (CI-PS4-3)

*Connections to DCIs across grade-bands:* **6.PS3.D** (CI-PS4-4); **8.PS4.A** (CI-PS4-1, CI-PS4-5); **8.PS4.B** (CI-PS4-1, CI-PS4-3, CI-PS4-4, CI-PS4-5); **8.PS4.C**,(CI-PS4-5); **6.ESS2.D** (CI-PS4-4); **6-8.ETS1.A** (CI4-ETS1-4); **6-8.ETS1.B** (CI4-ETS1-4); **6-8.ETS1.C** (CI4-ETS1-4)

*Connections to the Arkansas Disciplinary Literacy Standards:*

**RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (CI-PS4-3, CI-PS4-4)

**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (CI-PS4-3, CI-PS4-4)

**RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (CI-PS4-1, CI-PS4-4)

**RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (CI-PS4-3, CI-PS4-4)

**WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (CI-PS4-5)

**WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (CI-PS4-4)

*Connections to the Arkansas Mathematics Standards:*

**MP.2** Reason abstractly and quantitatively. (CI-PS4-1, CI-PS4-3, CI4-ETS1-4)

**MP.4** Model with mathematics. (CI-PS4-1, CI-ETS1-4)

**HSA.SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (CI-PS4-1, CI-PS4-3)

**HSA.SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression; factor a quadratic expression to reveal the zeros of the function it defines; complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines; use the properties of exponents to transform expressions for exponential functions. (CI-PS4-1, CI-PS4-3)

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| **HSA.CED.A.4** | Rearrange literal equations using the properties of equality. (CI-PS4-1, CI-PS4-3) |

## Topic 5: Forces

Students who demonstrate understanding can:

**CI-PS2-1** **Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.** [AR Clarification Statement: This PE is fully addressed in this course. Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force (a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force).] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

**CI-PS2-2** **Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

**CI-PS2-4** **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

**CI-PS3-5** **Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

**CI-ESS1-4** **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.** [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

**CI5-ETS1-2** **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.** [AR Clarification Statement: Examples of solutions could include satellite deployment, airbag design, gravity assist, sports safety, and elevators.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Analyzing and Interpreting Data**<br>Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.<br>▪ Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (CI-PS2-1) | **PS2.A: Forces and Motion**<br>▪ Newton's second law accurately predicts changes in the motion of macroscopic objects. (CI-PS2-1)<br>▪ Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (CI-PS2-2)<br>▪ If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is | **Patterns**<br>▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (CI-PS2-4)<br>**Cause and Effect**<br>▪ Empirical evidence is required to differentiate between cause and |

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| **Using Mathematics and Computational Thinking**<br>Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.<br>▪ Use mathematical representations of phenomena to describe explanations. (CI-PS2-2, CI-PS2-4, CI-ESS1-4)<br>**Developing and Using Models**<br>Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.<br>▪ Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (CI-PS3-2, CI-PS3-5)<br>**Constructing Explanations and Designing Solutions**<br>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.<br>▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (CI5-ETS1-2) | balanced by changes in the momentum of objects outside the system. (CI-PS2-2)<br>**PS2.B: Types of Interactions**<br>▪ Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (CI-PS2-4)<br>▪ Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (CI-PS2-4)<br>**PS3.C: Relationship Between Energy and Forces**<br>▪ When two objects interacting through a field change relative position, the energy stored in the field is changed. (CI-PS3-5)<br>**ESS1.B: Earth and the Solar System**<br>▪ Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (CI-ESS1-4)<br>**ETS1.C: Optimizing the Design Solution**<br>▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (CI5-ETS1-2) | correlation and make claims about specific causes and effects. (CI-PS2-1)<br>▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (CI-PS3-5)<br>**Systems and System Models**<br>▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (CI-PS2-2)<br>**Scale, Proportion, and Quantity**<br>▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (CI-ESS1-4)<br>-----------------------------------<br>***Connections to Engineering, Technology, and Applications of Science***<br>**Interdependence of Science, Engineering, and Technology**<br>▪ Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (CI-ESS1-4) |

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| --------------------------------------------------<br>***Connections to Nature of Science***<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>▪ Theories and laws provide explanations in science. (CI-PS2-1, CI-PS2-4)<br>▪ Laws are statements or descriptions of the relationships among observable phenomena. (CI-PS2-1, CI-PS2-4) | | |

*Connections to other DCIs in this course:* **CI.PS3.A** (HS-PS2-4); **CI.PS2.B** (CI-PS3-5, CI-ESS1-4); **CI.PS3.C** (CI-PS2-1); **CI.ESS1.A** (CI-PS2-1, CI-PS2-2, CI-PS2-4); **CI.ESS1.B** (CI-PS2-4); **CI.ESS1.C** (CI-PS2-1, CI-PS2-2, CI-PS2-4); **CI.ESS2.C** (CI-PS2-1, CI-PS2-4)

*Connections to DCIs across grade-bands:* **8.PS2.A** (CI-PS2-1, CI-PS2-2, CI-ESS1-4); **8.PS2.B** (CI-PS2-4, CI-PS3-5, CI-ESS1-4); **6.PS3.C** (CI-PS2-1, CI-PS2-2, CI-PS3-5); **8.ESS1.A** (CI-ESS1-4); **8.ESS1.B** (CI-PS2-4, CI-ESS1-4); **7.ESS2.B** (CI-ESS1-5); **6-8.ETS1.A** (CI5-ETS1-2); **6-8.ETS1.B** (CI5-ETS1-2); **6-8.ETS1.C** (CI5-ETS1-2)

*Connections to the Arkansas Disciplinary Literacy Standards:*

**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (CI-PS2-1)

**RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (CI-PS2-1)

**WHST.9-12.7** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.(CI-PS3-5)

**WHST.11-12.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (CI-PS3-5)

**WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. (CI-PS2-1, CI-PS3-5)

*Connections to the Arkansas English Language Arts Standards*

**SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (CI-PS3-5)

*Connections to the Arkansas Mathematics Standards*:

**MP.2** Reason abstractly and quantitatively. (CI-PS2-1, CI-PS2-2, CI-PS2-4, CI-PS3-5, CI-ESS1-4, CI-ESS1-5)

**MP.4** Model with mathematics. (CI-PS2-1, CI-PS2-2, CI-PS2-4, CI-PS3-5, CI-ESS1-4, CI5-ETS1-2)

**HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (CI-PS2-1, CI-PS2-2, CI-PS2-4, CI-ESS1-4, CI-ESS1-5)

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| **HSN.Q.A.2** | Define appropriate quantities for the purpose of descriptive modeling. (CI-PS2-1, CI-PS2-2, CI-PS2-4, CI-ESS1-4, CI-ESS1-5) |
| **HSN.Q.A.3** | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (CI-PS2-1, CI-PS2-2, CI-PS2-4, CI-ESS1-4, CI-ESS1-5) |
| **HSA.SSE.A.1** | Interpret expressions that represent a quantity in terms of its context; interpret parts of an expression using appropriate vocabulary, such as terms, factors, and coefficients; interpret complicated expressions by viewing one or more of their parts as a single entity. (CI-PS2-1, CI-PS2-4, CI-ESS1-4) |
| **HSA.SSE.B.3** | Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression; factor a quadratic expressions to reveal the zeros of the function it defines; complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines; use the properties of exponents to transform expressions for exponential functions. (CI-PS2-1, CI-PS2-4) |
| **HSA.CED.A.1** | Create equations and inequalities in one variable and use them to solve problems. (CI-PS2-1, CI-PS2-2) |
| **HSA.CED.A.2** | Create equations in two or more variables to represent relationships between quantities; graph equations. In two variables, on a coordinate plane. (CI-PS2-1, CI-PS2-2, CI-ESS1-4) |
| **HSA.CED.A.4** | Rearrange literal equations using the properties of equality. (CI-PS2-1, CI-PS2-2, CI-ESS1-4) |
| **HSF.IF.C.7** | Graph functions expressed symbolically and show key features of the graph, with and without technology; graph linear and quadratic functions and, when applicable, show intercepts, maxima, and minima; graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions; graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior; graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior; graph exponential and logarithmic functions, showing intercepts and end behavior; graph trigonometric functions, showing period, midline, and amplitude. (CI-PS2-1) |
| **HSS.ID.A.1** | Represent data with plots on the real number line (dot plots, histograms, and box plots). (CI-PS2-1) |

## Contributors

The following educators contributed to the development of this course:

| | |
|---|---|
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| Sarah Croswell – Virtual Arkansas | John Nilz – North Little Rock School District |
| Tami Eggensperger – Cabot School District | Dennis Pevey – eSTEM Public Charter School |
| Jenna Gill – Siloam Springs School District | Tami Philyaw – Smackover – Norphlet School District |
| Douglas Hammon – Little Rock School District | Kathy Prophet – Springdale School District |
| Keith Harris – University of Arkansas at Little Rock Partnership for STEM Education | Carrie Shell – Highland School District |
| Lynne Hehr – University of Arkansas at Fayetteville STEM Center for Math and Science Education – | Will Squires – Caddo Hills School District |
| Leonda Holthoff – Star City School District | Eddie Tucker – Hamburg School District |
| Courtney Jones – Lincoln Consolidated School District | Jon White – Harding University |
| Rebecca Koelling – Highland School District | Andrew Williams – University of Arkansas at Monticello |
| Karen Ladd – Nettleton School District | Wendi J.W. Williams – Northwest Arkansas Community College |
| John Levy – North Arkansas College | Cathy Wissehr – University of Arkansas at Fayetteville |